AERONOMY LABORATORY
Accomplishments

List 3-5 major accomplishments for your laboratory. If accomplishment occurred more than 2 years ago, cite recent progress. Please specify importance of accomplishment, who have been the major users and what has been the benefit to the taxpayer.

(1) Antarctic ozone hole research: A defining achievement of the Aeronomy Laboratory.

Aeronomy Laboratory scientists have been pivotal in understanding and describing the atmospheric processes that cause the unexpected occurrence of the Antarctic ozone hole and, more recently, the linkages between the ozone hole and climate in the Antarctic region.

- Shortly after the discovery of the Antarctic ozone hole in 1985, an Aeronomy Laboratory scientist proposed a theory, invoking a new kind of chemical interaction, for the cause of the extreme losses of stratospheric ozone in the Antarctic springtime. The theory proposed that human-produced chlorine compounds interact with the polar stratospheric ice clouds (PSCs) and unique Antarctic meteorology to produce the hole in the ozone layer.
- The Aeronomy Laboratory led the 1986 and 1987 interagency field missions to try to determine which, if any, of the theories proposed by the international scientific community could be the correct explanation of the ozone hole. The Aeronomy Laboratory theory was proven correct.
- The Aeronomy Laboratory has subsequently been at the forefront of the new area of atmospheric chemistry research that was, in large part, spawned by the Antarctic ozone hole discoveries. Namely, "heterogeneous chemistry," which studies the interaction of gases with particles in the atmosphere such as the PSCs or particles formed from volcanic emissions, is now a vigorous research area with implications for the ozone-layer, climate, and air quality.
- Aeronomy Laboratory research in 2002/2003 has shown that the occurrence of the ozone hole is a cause of anomalous surface temperature patterns now occurring at the surface of the Antarctic continent and peninsula (a definitive ozone layer/climate connection).

<u>Users and benefits</u>

This research has provided the scientific basis for national and international decisions to protect the ozone layer, namely, the U.S. Clean Air Act and the United Nations Montreal Protocol on Substances that Deplete the Ozone Layer. Those decisions have been directly credited with global achievements in dramatically curtailing the use of ozone-depleting substances. The initial expectations of runaway depletion of the ozone layer have been transformed by these agreements into expectations of recovery of the stratospheric ozone layer by the middle of the 21st Century. An ultimate, and perhaps incalculable, benefit to the U.S. taxpayer and to citizens worldwide is the protection of the public from detrimental effects of excessive exposure to ultraviolet radiation that would have occurred with a thinner ozone layer. It is estimated that without the international agreements of the Montreal Protocol, an additional 1.5 *million* skin cancer cases would occur *per year* in the U.S. alone.

(2) Evaluating of ozone friendliness and climate friendliness of chemical compounds.

The Aeronomy Laboratory has been the "honest broker" of information about the ozone-layer friendliness and climate friendliness of substances that industry proposes for a variety of societal uses such as refrigeration, air conditioning, electronics manufacture, and fire protection. Early information about the suitability of a proposed substance is needed by industry *before* costly development investments are made.

- Over the past ~15 years, the Aeronomy Laboratory has carried out laboratory and modeling evaluations of over a dozen substances and gained the reputation among industries and governments as the "go-to" laboratory for such information.
  - In one case, the Aeronomy Laboratory's quick-response findings confirmed the ozone friendliness of a new air conditioning coolant about which doubts had been raised unexpectedly, thereby preventing a costly recall by the automobile industry of thousands of new vehicles that had just been outfitted with the new coolant (HFC-134a, now in widespread use).
  - In other example, the Aeronomy Laboratory's research demonstrated that a set of compounds known as "perfluorocarbons" have exceedingly long lifetimes, making them molecule-for-molecule among the most potent greenhouse gases known. Industry acted voluntarily on those findings, choosing not to use the perfluorocarbons as replacements for ozone-depleting substances such as the CFCs.
- The Aeronomy Laboratory is a leader of current research in developing approaches to assess the ozone friendliness of a new class of very short-lived substances, which industry is increasingly turning to as alternatives to ozone-depleting substances.

<u>Users and benefits</u>

This Aeronomy Laboratory research has positioned DOC/NOAA as the honest broker of timely scientific results needed to avoid expensive false starts or unnecessary delays in the development of ozone-friendly and climate-friendly alternatives. It is estimated that industry (and ultimately the consumer) is spared about $25M per startup facility when a false start is averted by having an *early* picture of how ozone friendly and climate friendly a proposed new compound would be. By providing industry the earliest possible assessment of proposed new substances, the research has opened new markets, has kept the international progress to protect the ozone layer "on track," and has supported the nation's efforts in the climate arena. In addition, the U.S. Environmental Protection Agency needs such information about the ozone-layer friendliness of proposed substances, in order to meet U.S. obligations under the U.S. Clean Air Act and the international Montreal Protocol on Substances that Deplete the Ozone Layer.

(3) Elucidating the chemistry that underlies the radiative properties of Earth's atmosphere.

The Aeronomy Laboratory has made a suite of accomplishments that have advanced scientific understanding of the atmospheric chemical processes that underlie the radiative properties of the atmosphere and that contribute to the NOAA Climate Program.

- Determined relative effectiveness of various greenhouse gases in the atmosphere. The Aeronomy Laboratory has been a leader of theoretical and laboratory research to determine the global warming potentials (GWPs) of heat-absorbing atmospheric gases. For example, Aeronomy Laboratory research on methane, a relatively short-lived greenhouse gas, uncovered errors in the prevailing understanding of the lifetime of methane in the atmosphere and led to the discovery that the GWP of methane is actually about 25% higher than had been thought. The GWPs are a "yardstick" that compares the relative warming effectiveness of different greenhouse gases. They are used by decisionmakers worldwide to determine which gases might be the most effective focus of future actions regarding climate. The GWP information is also useful to industries developing new substances, as a gauge of the "climate friendliness" of the proposed new compound.
- Using new and past observations, determined that tropospheric ozone levels in air coming ashore at the U.S. West Coast has increased by about 30% (~10 parts per billion by volume) near the surface over the past two decades, demonstrating that a "natural," unperturbed Pacific no longer exists. The increase in this greenhouse gas influences the radiative forcing of climate, and also has implications for the regional air quality on the U.S. West Coast.
- Pioneered research on the formation of small particles (aerosols) in the atmosphere. Aerosol particles play a major role in the absorption of radiation as well as in cloud formation, but little was known about the processes involved in the aerosols' formation. The Aeronomy Laboratory has been at the forefront of this new research area. The research has led to new insights into of the role of charged particles (ions) in the formation of aerosols, and observations in some regions appear to be consistent with this new perspective.
- Expanded the understanding of the absorption properties of water vapor, the most pervasive of the major greenhouse gases in the atmosphere. This Aeronomy Laboratory research has enabled a more precise determination of the amount of incoming solar radiation absorbed by the atmosphere, and hence contributes to improved understanding of the Earth's radiation balance.
- Developed and applied a new measurement method to provide real-time, in-situ analysis of the chemical composition of *individual* atmospheric particles, a first-time capability in the atmospheric sciences. Field measurements using the method have provided new information about the chemical makeup of atmospheric particles that are effective in causing cloud formation. The result runs counter to existing scientific preconceptions and brings a new accuracy to the modeling and prediction of cloud formation processes. Further, the information on chemical makeup of aerosols is helping "fingerprint" the individual (and varied) sources of the particles, such as biomass burning.

<u>Users and benefits</u>

This increasing focus of Aeronomy Laboratory research is helping to reduce many of the uncertainties in climate science. The subject of aerosol-related processes is an area in which large and policy-relevant gains can be made. It is deemed one of the nation's top priorities by the President's Climate Change Research Initiative and the U.S. Climate Change Science Program (CCSP). NOAA is a Co-Lead that is responsible for a 2006 CCSP deliverable on aerosol-climate interactions. Because aerosol lifetimes are relatively short in the atmosphere, this research is contributing to the development of potential options that could reduce the radiative forcing of climate in the coming decade or so. Further, since aerosols are also a growing human-health issue, this research is helping identify potential "win-win" options in climate and air quality.

(4) The Aeronomy Laboratory's regional air chemistry discoveries: Setting a course for developing a new NOAA air quality forecasting service.

The "discovery-to-operations" air quality accomplishments span over three decades of Aeronomy Laboratory research.

- In the 1970s-1980s, the Laboratory's back-to-basics diagnostic studies identified and quantified the natural sources of acidity in the atmosphere. By filling in this "missing link" in the scientific picture of acid rain, the Aeronomy Laboratory's research contributed to providing policymakers the necessary defendable context in which to consider human influences.
- Subsequent diagnostic studies in the 1980s and 1990s on surface-level pollutant ozone discovered the relative contributions of naturally emitted starting ingredients, which overwhelmed the comparable anthropogenic emission in many areas. The research pointed the way toward a more effective approach to improving air quality and, in the process, helped decisionmakers avoid costly miscues in the actions taken (i.e., "working against Ms. Nature").
- In the late 1990s and continuing to the present, the Aeronomy Laboratory's air quality research has continued to show that one must "expect the unexpected" on this scientific topic. Namely, contrary to the then-common policy approach, the factors that govern air quality for one area of the country are not necessarily the same as the factors that are at work in another area ("one size does not fit all"). Aeronomy Laboratory diagnostic studies have yielded findings of practical and very immediate interest for several parts of the U.S.:
  - *In the eastern U.S.*: Smaller coal-fired electric-generating power plants produce more ozone pollution per unit of power generated than do larger power plants, a finding that has implications for future design decisions of the energy industry. Further, Aeronomy Laboratory research demonstrated that the pollution per unit power also depends on the ambient chemical background of the air in the region of the power plant, and therefore the location of the power plant is a factor (i.e., "location, location, location").
  - *In the New England region*: Nighttime chemical processes, as well as coupling between land and offshore processes, are more important to the region's air quality than previously thought. Their incorporation into air quality prediction models will lead to improved air quality forecasts for New England.
  - *In the Houston region*: Fugitive emissions (leaks) from the petrochemical industry are a much, much larger influence on the region's air quality than had been previously estimated, a result that has altered the policy approach taken by Texas air quality managers (at a savings of 70,000 jobs and $1B in Texas). As noted by the Deputy Director of the Texas Commission on Environmental Quality (the lead environmental agency for the State of Texas) in a 9 September 2003 letter to VADM Lautenbacher, "NOAA's discoveries during the [TexAQS2000] study have allowed for the development of cost-effective strategies that will result in cleaner air."

<u>Users and benefits</u>

The discoveries of the Aeronomy Laboratory's atmospheric-chemistry process studies have enabled the nation's air quality management efforts to become both more effective and more cost efficient. Further, the cumulative process-level understanding from this Aeronomy Laboratory research is laying the scientific groundwork for developing an air quality forecasting capability within NOAA, since model forecasts are only as good as their representativeness of the "real" atmosphere. This joint OAR/NWS effort is expected to culminate fully into an operational air quality forecast service within this decade. Such forecasts will protect the public from the harmful health effects of exposure to poor air quality (e.g., in susceptible populations like asthmatics), which will translate into benefits and savings for the nation's citizens and businesses.

(5) Leadership in delivering information products to decisionmakers on the ozone layer, climate, and air quality: Scientific state-of-understanding assessments.

A hallmark of the Aeronomy Laboratory is its special emphasis on communicating discoveries, predictions, and other scientific information in a form that meets the needs of end users in government, industry, and international relations. The Aeronomy Laboratory has been at the forefront of leading the dialogue between researchers and information users that provides that information service via periodic international state-of-scientific-understanding updates ("assessments") on the topics of the stratospheric ozone layer, climate, and air quality.

- The Aeronomy Laboratory has led the international ozone-layer assessments since their inception.
  - An Aeronomy Laboratory scientist has served as Cochair (since 1989) of the ozone-layer assessments, which have occurred in 1989, 1991, 1994, 1998, and 2002 (forthcoming assessment in 2006). In this capacity, the Aeronomy Laboratory has interacted with governments and industry to learn their needs, and has then described and presented the findings of the assessments to the over 170 nations that are Parties to the international ozone-layer agreement (the United Nations Montreal Protocol on Substances that Deplete the Ozone Layer) and world industry leaders.
  - Aeronomy Laboratory scientists have made extensive contributions as leading authors, coauthors, contributors, peer reviewers, and coordinating editor throughout the ozone-layer assessment's history.
  - Through its leadership and extensive participation in the international ozone-layer assessments, the Aeronomy Laboratory have delivered scientific information that directly addresses immediate needs of the world's decisionmakers. As noted by public policy expert Edward A. Parson in his 2003 book *Protecting the Ozone Layer*, "…statements in official scientific assessments did move major actors to change positions, resolve debates over contested policy-relevant claims, and stimulate the formation of policy coalitions."
- The Aeronomy Laboratory has had an increasing role in the international climate assessments of the Intergovernmental Panel on Climate Change (IPCC). In addition to continuing roles as authors, contributors, and reviewers, Aeronomy Laboratory scientists have more recently added these high-profile roles: (i) the lead authorship of the widely read *Summary for Policymakers and Technical Summary* of the 2001 assessment report, and (ii) the election in 2002 of an Aeronomy Laboratory scientist to Cochair of the IPCC's scientific working group, whose Technical Support Unit is housed at the Aeronomy Laboratory. The IPCC has begun its preparation of the 2007 Fourth Assessment Report.
- Aeronomy Laboratory scientists have also been steering committee members, lead authors, and reviewers of the international scientific assessments on the air quality topics of surface-level ozone and fine-particle pollution, as well as the scientific assessment of the atmospheric effects of aviation.

<u>Users and benefits</u>

The Aeronomy Laboratory's cumulative (15-plus years) contribution has forged a "blueprint" for the global and regional scientific assessment process. These assessments are key products in NOAA's information-providing mission. Through its leadership in scientific assessments since their very inception with the ozone-layer issue, the Aeronomy Laboratory ensures that NOAA's research findings (and, indeed, the world's) reach decisionmakers in a timely, user-friendly format to meet their information needs with regard to societal decisions on the ozone layer, climate, and air quality. The scientific basis of decisions is enhanced through this end-to-end, cyclic information service, thereby providing "one-stop shopping" for information on issues, serving as a "touchstone" of credibility, and ultimately sparing the taxpayer the expense of unnecessary or ineffective actions.